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Cost Comparison of Gob Hole and Cross-Measure Borehole Systems To Control Methane in Gobs

By Eugene C. Baker, Fred Garcia, and Joseph Cervik

UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 9151

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	m	meter
ft	foot	m^3/d	cubic meter per day
ft/wk	foot per week	m/wk	meter per week
h	hour	$MMft^3$	million cubic feet
h/d	hour per day	$MMft^3/d$	million cubic feet per day
hp	horsepower	pct	percent
h/yr	hour per year	pct/yr	percent per year
in	inch	yr	year
kW	kilowatt		
kW•h	kilowatt hour		

COST COMPARISON OF GOB HOLE AND CROSS-MEASURE BOREHOLE SYSTEMS TO CONTROL METHANE IN GOBS

By Eugene C. Baker,[1] Fred Garcia,[2] and Joseph Cervik[3]

ABSTRACT

The capital investment and operating costs of two methane-control systems used during longwall mining operations are compared in this Bureau of Mines report. Costs are given for a surface gob hole drainage system and an underground cross-measure borehole drainage system to control methane gas in gobs in four coal mining areas--central Pennsylvania, northern West Virginia, southern Virginia, and northern Alabama. Present-worth analysis is used to determine the more cost-effective alternative in each location. The alternatives have equal lives and provide the same service based on a minimum rate of return of 15 pct.

In central Pennsylvania and northern West Virginia, the gob hole system is more cost effective than the cross-measure system, by 10 and 18 pct, respectively. In southern Virginia and northern Alabama, the cross-measure system is more cost effective, by 29 and 38 pct, respectively. Costs for other locations must be developed on a case-by-case basis.

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INTRODUCTION

Methane emitted from fractured roof strata during longwall mining operations in the United States is diluted with ventilation air as a control measure. When ventilation alone is insufficient to control the methane level, gob gas drainage through surface gob holes is the most common supplemental method used in the United States. The gob gas is drawn to the surface by natural draft or a partial vacuum created by a surface exhauster and thus is prevented from entering the ventilation system. However, surface gob holes cannot always be drilled, because of severe topography, surface right-of-way problems, and populated areas. Consequently, when one or more of these conditions exist, an alternative method is needed to supplement mine ventilation.

The underground cross-measure borehole technique has been shown by the Bureau of Mines to be an effective method of controlling methane in longwall gobs, if access to the pipeline and cross-measure boreholes can be maintained during the life of the longwall. Cross-measure boreholes are drilled prior to mining from underground locations into the roof strata above the longwall panel. When the strata are fractured by longwall mining, suction is applied to these holes by a surface exhauster. The gob gas is transported to the surface through an underground pipeline and surface borehole.

The objective of this report is to compare the costs of the cross-measure and surface gob hole systems. Cost comparisons were developed for four mining areas: central Pennsylvania [overburden, 600 ft (183 m)], Northern West Virginia [overburden 900 ft (247 m)], southern Virginia [overburden 1,800 ft (549 m)], and northern Alabama [overburden 2,050 ft (625 m)]. The equipment and techniques used in the cross-measure system are well documented in published Bureau reports (1, 3, 5).[4] Surface gob holes have been used by the mining industry since the early 1970's. The drilling and completion procedures and the cost of capital goods used are well known to the coal mining industry.

Where the cross-measure technique is used, entries must remain open to service the underground pipeline and cross-measure boreholes during the life of the longwall. In the southern Virginia and northern Alabama areas, some mines--because of severe damage to the roof and floor in the tailgate--now use yield pillars rather than stiff chain pillars to support the gate roads. This yield pillar design precludes the use of cross-measure boreholes for gob gas control because the entries collapse. Use of the cross-measure technique would require an increase in the size of the chain pillars in these deeper coalbeds, which, however, would lower the rate of advance and decrease the extraction ratio (2).

ACKNOWLEDGMENTS

The authors thank the following personnel for their cooperation and assistance in providing information and cost data: D. Weaver, geologic engineer, Bethlehem Mines Corp., Cambria Division, Ebensburg, PA; Jack Stevenson, manager, ventilation, Jim Walter Resources, Brookwood, AL; P. C. Thakur, group leader, Methane and Ventilation Group, Conoco Coal Research Division, Morgantown, WV; and Leonard P. Mokwa, manager, Mining Engineering, Island Creek Coal Co., Oakwood, VA.

[4]Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

COST CATEGORIES

Capital and operating costs were determined for 11 categories of equipment and services (table 1). Six capital investment categories are common to the surface gob hole and cross-measure systems, and two categories are unique to the cross-measure system. There are three operating cost categories; two are common to both systems and one is unique to the cross-measure system.

The purchase of capital items listed under the categories of "development," "surface equipment," and "cross-measure drilling and drainage equipment" (table 1) is done by company personnel. Development includes project planning, surveying and mapping, training, and purchasing of drilling rights. Project planning establishes drilling parameters and the quantity and size of equipment and material required. Surveying and mapping locate the surface gob holes, vertical boreholes associated with the cross-measure system, cross-measure boreholes, and the underground pipeline. Training is a service given to underground personnel to teach cross-measure borehole drilling procedures and maintenance of the underground methane pipeline. Surface drilling rights for gob holes or vertical boreholes associated with the cross-measure systems are purchased from the independent land owner.

Site preparation and gob hole or vertical borehole drilling services (table 1) are capital costs paid to an outside contractor. Operating cost items listed under categories of "cross-measure drilling" and "surface operation" are services performed by the company. "Surface operation" includes methane sampling, equipment maintenance, and sealing of gob holes and vertical boreholes after they have served their useful purpose. "Supervision, office, general overhead, and contingency" is a category associated with both capital and operations costs.

TABLE 1. - Capital and operating cost categories[1]

	Surface gob hole system	Cross-measure system
CAPITAL COSTS		
Development	*	*
Site preparation	*	*
Surface equipment	*	*
Gob hole or vertical borehole:[2]		
Equipment	*	*
Drilling	*	*
Cross-measure:		
Drilling equipment	NAp	*
Drainage equipment	NAp	*
Supervision, office, general overhead, and contingency	*	*
OPERATING COSTS		
Cross-measure drilling	NAp	*
Surface operation	*	*
Supervision, office, general overhead, and contingency	*	*

NAP Not applicable.

[1]Cost of items included in the categories are detailed in the appendix.

[2]Vertical borehole equipment and vertical borehole drilling are associated with the cross-measure system.

MINING AND GOB GAS DRAINAGE DESIGN

LONGWALL AND GAS PRODUCTION

For each mining area, costs for controlling gob gas were determined for seven longwall panels using surface gob holes and seven panels using the cross-measure borehole system (fig. 1). The panels are 5,000 ft (152 m) long and 600 ft (183 m) wide. The mining rate is 150 ft/wk (46 m/wk) in central Pennsylvania, northern West Virginia, and southern Virginia and 188 ft/wk (57 m/wk) in northern Alabama. The mining rates are characteristic of mines in these areas. Mining is conducted with two shifts per day on a 5-d/wk schedule. Seven days are assumed to be required to move mining equipment from a mined-out panel to the adjacent panel to be mined.

Generally, gas content of overburden strata increases with depth. The design of the cross-measure and surface gob hole systems depends upon the quantity of methane released when the roof strata are fractured by the longwall operations. Both systems have been designed to handle 1 MMft^3/d (28,300 m^3/d) of methane in the central Pennsylvania area and 2 MMft^3/d) (56,600 m^3/d) in the northern West Virginia area. In deeper coalbeds, breakup of roof strata releases 5 to 6 MMft^3/d (141,600 to 169,900 m^3/d) of methane in the northern Alabama area (6) and about 17 MMft^3/d (481,450 m^3/d) in southern Virginia (4). Consequently, the surface gob hole and cross-measure systems have been designed to handle 4 MMft^3/d (141,600 m^3/d) in the northern Alabama area and 14 MMft^3/d (396,500 m^3/d) in the southern Virginia area.

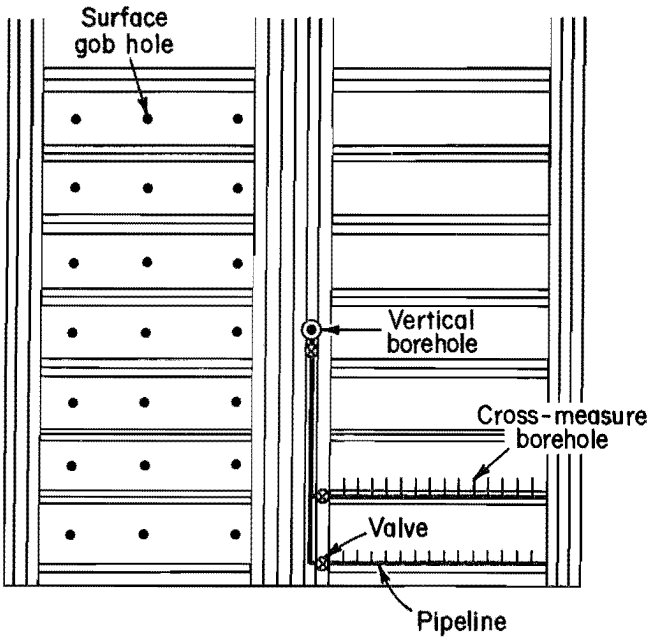

FIGURE 1.—Surface gob hole and cross-measure mine plans.

SURFACE GOB HOLE SYSTEM

In the central Pennsylvania and northern West Virginia areas, three gob holes are drilled into each longwall panel (fig. 2). The first gob hole is drilled about 400 ft (122 m) from the start line of the panel and the other two are equally spaced over the remaining length of the panel. In the deeper coalbeds where the overlying strata are gassier than at shallow depths, four gob holes are used in each panel (fig. 3). In southern Virginia, the first gob hole is located about 300 ft (91 m) from the start line of the panel and the other three holes are spaced 1,200 ft (366 m apart (fig. 4*A*). In northern Alabama, the gob holes are drilled about 500, 1,000, 1,800, and 2,800 ft (152, 305, 549, and 854 m) from the start line of the panel (fig. 4*B*).

Gob hole completion differs in each of the study areas because of hole size, size of casing, and depth of hole. The factors that affect the cost of gob hole completion are discussed below.

In central Pennsylvania, the gob holes are 600 ft (183 m) deep. Initially, a

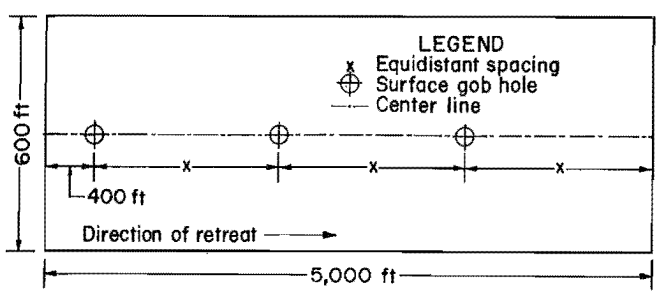

FIGURE 2.—Longwall gob hole locations for central Pennsylvania and northern West Virginia.

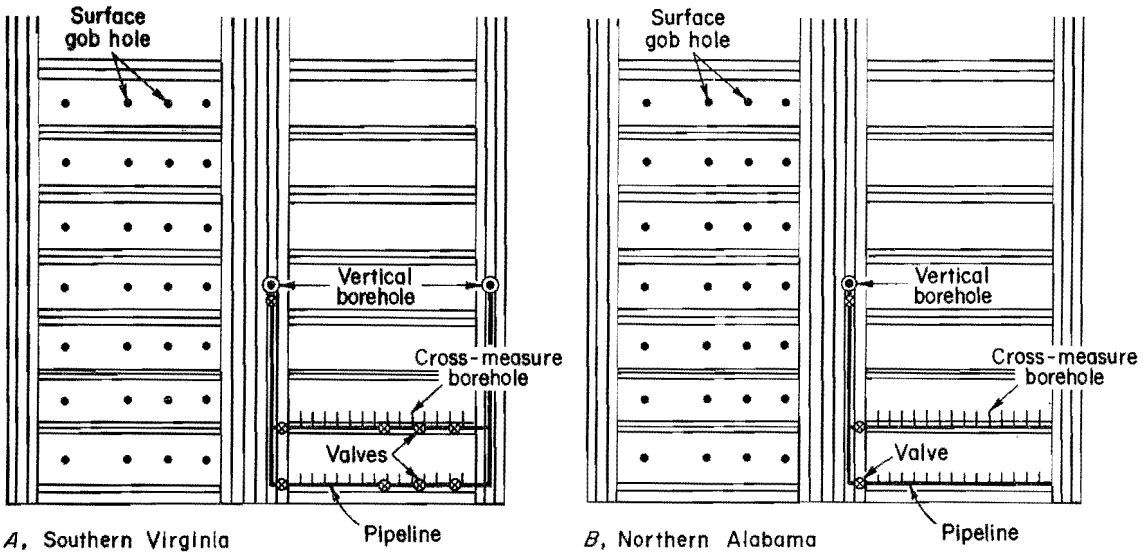

FIGURE 3.—Surface gob hole and cross-measure systems for southern Virginia and northern Alabama.

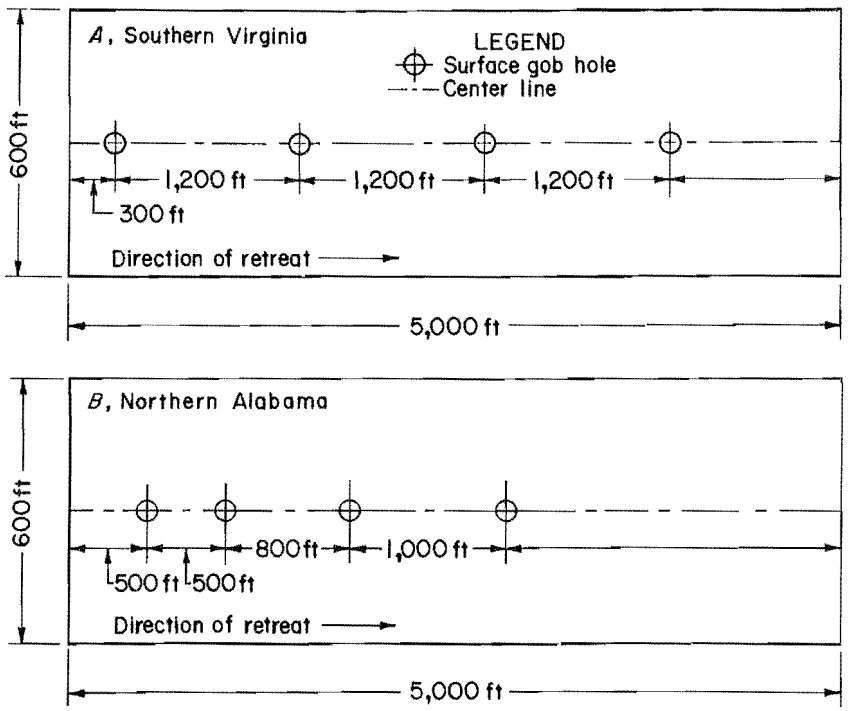

FIGURE 4.—Longwall gob hole locations for southern Virginia and northern Alabama.

12-in (30.5-cm) diam hole is drilled to 500 ft (152 m). An 8-in (20.3-m) casing is set to the bottom of the hole, and a bottom seal arrangement is installed. The hole is then extended an additional 100 ft (30.5 m) with an 8-in (20.3-cm) bit. This later section is not cased. The 8-in (20.3-cm) casing is sealed with 21 in (53.3 cm) of grout at about the 500-ft (152-m) depth.

Gob holes in the northern West Virginia area are drilled to a depth of 900 ft (274 m) with an 8.75-in (22.2-cm) bit. The hole is then lined with 700 ft (213 m) of 7-in (17.8-cm) standard casing and 200 ft (61 m) of 7-in (17.8-cm) slotted casing. A formation packer, which is installed above the slotted casing, allows the 700-ft (213-m) length of casing to be grouted in place. The slotted casing that hangs below the formation packer extends to within 20 to 90 ft (6.1 to 27.4 m) of the coalbed.

In southern Virginia, average overburden is about 1,800 ft (549 m). Gob holes are drilled to within 20 ft (6.1 m) of the coalbed with a 12.25-in (31.1-cm) bit. The hole is then lined with 1,600 ft (488 m) of 9-in (22.9-cm) casing and 180 ft (55 m) of slotted casing. A formation packer, which is installed above the slotted casing, allows the 1,600 ft (488 m) of casing to be grouted in place.

Gob holes are about 2,050-ft (625-m) deep in northern Alabama. Initially, a 17.5-in (44.5-cm) hole is drilled to 150 ft (46 m) and a 13.38-in (34-cm) casing is grouted in place. Subsequently, the hole is extended about 1,880 ft (573 m) to within 20 ft (6.1 m) of the coalbed using a 12.25-in (31.1-cm) bit. The hole is then lined with 1,450 ft (442 m) of 9.63-in (24.4-cm) casing and 400 ft (122 m) of 9.63-in (24.4-cm) slotted casing. A formation packer is installed above the slotted casing and the top 1,450 ft (442 m) of casing is grouted in place.

All gob holes are equipped with exhausters to provide the partial vacuum to draw the gob gas to the surface. The size and capacity of the exhausters are dependent on the gassiness of the strata in the study area (table 2). The surface venting facilities are fenced and equipped with lightning protectors and flame arrestors.

TABLE 2. - Gob hole exhausters

Area	Methane drained, $MMft^3$	Exhauster size, hp
Central Pennsylvania..	1.0	15
Northern West Virginia	2.0	20
Southern Virginia.....	14.0	100
Northern Alabama.....	4.0	40

CROSS-MEASURE SYSTEM

The cross-measure system has four main components: cross-measure boreholes, the underground methane pipeline, one or two vertical boreholes, and exhausters. The cross-measure boreholes are connected through a piping arrangement to the underground pipeline (fig. 5), which in turn is joined to a vertical borehole. A surface exhauster on the vertical borehole is used to produce a partial vacuum in the underground pipeline and at each cross-measure borehole to draw the gas from the gob to the surface where it is vented to the atmosphere.

A bare copper wire is wrapped around all underground polyethylene pipelines. The wire is grounded to prevent buildup of static charges. The surface venting facilities are fenced and equipped with lightning protectors and flame arrestors.

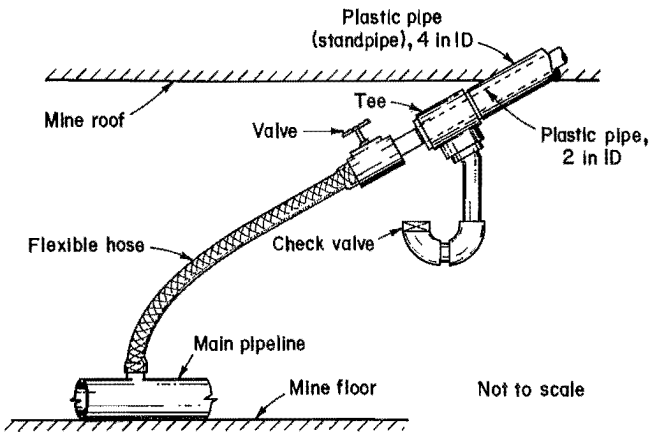

FIGURE 5.—Underground piping arrangement.

Central Pennsylvania and Northern West Virginia

Figure 1 shows a typical layout for the cross-measure system in the central Pennsylvania and northern West Virginia areas. One 8.75-in (22.2-cm) vertical borehole is drilled into a main return airway near the middle of the set of panels, and it services the seven panels. The vertical borehole is equipped with 15- and 50-hp (11- and 37-kW) exhausters in the central Pennsylvania area. The smaller exhauster is used initially to accommodate the flow from a few cross-measure boreholes. As mining advances, more boreholes are intercepted and gas flows begin to approach the capacity of the smaller exhauster. The larger exhauster is then brought on-line and used for the remainder of the panel. In the northern West Virginia area, two 60-hp (45-kW) exhausters are used because of the potential for much larger quantities of gob gas than in the central Pennsylvania area. The two 60-hp (45-kW) exhausters are connected in series to increase the partial vacuum of the system.

Initially, 8-in (20.3-cm) polyethylene pipelines are laid in the return airways of the first two panels (fig. 1). When the first panel has been mined, the pipeline is dismantled and moved to a return entry along the third panel. When the second panel is completed, the pipeline is dismantled and moved to the fourth panel. This procedure is followed until the seven panels have been mined.

The cross-measure boreholes are spaced 200 ft (61 m) apart, except along the first 600 ft (183 m) of the panel where the spacing is reduced to 100 ft (30.5 m). More holes are needed near the start of the longwall to capture the large quantities of gob gas produced when the first large roof fall occurs. The total number of boreholes drilled over each panel is 27. These holes are initially core-drilled for 20 ft (6.1 m) with a 6-in bit (15.2-cm), and the remainder of the 280-ft (85-m) hole is drilled with a 1.9-in (4.8-cm) bit. When drilling is completed, a 4-in (10.2-cm) plastic standpipe, 20-ft (6.1-m) long, is grouted into the collar of the hole. The standpipe provides the means of connecting the cross-measure hole to the underground pipeline (fig. 5).

Southern Virginia

Figure 3A shows the cross-measure system layout in the southern Virginia area. Two 12.25-in (31.12-cm) vertical boreholes are drilled into return airways near the middle of the set of panels. The holes are then lined with 9.63-in (24.45-cm) casing. In general, flows from half the cross-measure boreholes along the panel are vented at each vertical borehole. Two holes are required to prevent large gas pressure drops in the underground pipeline and vertical boreholes because of the tremendous quantities of gob gas [14 $MMft^3/d$ (396,500 m^3/d)] to be handled by the cross-measure system. One vertical borehole is equipped with 60- and 350-hp (45- and 261-kW) exhausters. The other vertical borehole is equipped with 200- and 350-hp (149- and 261-kW) exhausters. When only a few cross-measure boreholes have been intercepted, the 60-hp (45-kW) exhauster is used. As more boreholes are intercepted, the 350-hp (261-kW) exhauster is brought on-line. As the panel is retreated farther, the 200-hp (149-kW) exhauster on the other vertical borehole is started. Valves in the underground pipeline prevent interference between exhausters. The manipulation of valves and exhausters is continued until the 350-hp (262-kW) exhausters on each vertical borehole are in operation. An 8-in (20.3-cm) polyethylene pipeline arrangement is laid in the return airway prior to mining the panel.

Cross-measure boreholes are spaced 100 ft (30.5 m) apart, except for the first 200 ft (61 m) of the panel where the spacing is 50 ft (15.2 m). The total number of boreholes over each panels is 54. The boreholes are drilled 280 ft (85 m) in length with a 2.5-in (6.4-cm) bit. Larger diameter holes are used

in this area than in central Pennsylvania in order to keep gas pressure drops to a minimum. Standpipes are grouted into each borehole after drilling is completed.

Northern Alabama

The mine layout for the cross-measure system in northern Alabama is shown in figure 3*B*. One 17.5-in (44.5-cm) vertical borehole is drilled to 150 ft (46 m) and a 13.38-in (34-cm) casing is grouted in place. Subsequently, the hole is extended about 1,900 ft (579 m) into the return airway near the middle of the set of panels. The vertical borehole is equipped with one 60- and two 100-hp (45- and 75-kW) surface exhausters. The two larger exhausters are connected in series to increase the partial vacuum of the system. An 8-in (20.3-cm) polyethylene pipeline is installed in the return airway before the panel is mined.

Cross-measure boreholes are drilled with a 1.9-in (4.8-cm) bit and are 280 ft (85 m) long. A total of 37 boreholes are drilled over each panel. Borehole spacing is 100 ft (30.5 m) along the first 2,500 ft (762 m) of the panel and 200 ft (61 m) apart over the remainder of the panel.

GOB GAS DRAINAGE PLAN

The operating cost category "surface operation" is common to the gob hole and cross-measure systems (table 1). It consists of monitoring gas flows, sampling gas, and maintaining the surface exhausters. In central Pennsylvania, northern West Virginia, and southern Virginia areas, the seven longwalls are mined in 54.25 months and gob gas drainage is continued on the last panel for an additional 5.75 months. In the northern Alabama area, mining is completed in 42 months and gob gas drainage on the last panel is continued for an additional 6.0 months.

SURFACE GOB HOLE SYSTEM

In year 0 (1985), development work, gob hole site preparation, and purchase of surface equipment for the first two panels are completed. In years 1 and 2, surface gob holes are drilled and surface equipment is installed on two panels each year in the central Pennsylvania and northern West Virginia areas. Similar work is completed on one panel in each of the years 3 through 5. In the sourthern Virginia area, where four gob holes are drilled into each panel, surface gob holes are drilled and surface equipment is installed on 1.5 panel each year during years 1 through 4. In year 5, similar work is completed on the last panel.

In northern Alabama, surface gob holes are drilled and surface equipment is installed on two panels each year in years 1 through 3 and the last panel in year 4. (The seven panels are mined in 4 yr compared with 5 yr for the other study areas because of the faster mining rate in the northern Alabama area.)

CROSS-MEASURE SYSTEM

In year 0 (1985), development work and site preparation for the vertical borehole are completed. In addition, surface equipment for extracting gob gas and cross-measure drilling and drainage equipment are purchased. In year 1, the vertical borehole is drilled and surface equipment is installed. Concurrently, the underground methane pipeline is installed and the cross-measure drilling program and the surface operation are started. Vertical borehole drilling equipment and services are supplied by an outside contractor. Underground cross-measure drilling is conducted by company personnel.

In central Pennsylvania and northern Alabama, 27 cross-measure boreholes are drilled, and standpipes are grouted into each borehole on each of two panels in years 1 and 2 and on one panel in each of the years 3 through 5. In southern Virginia, 54 boreholes are completed on

each of two panels in years 1 and 2 and on one panel in each year 3 through 5. Thirty-seven cross-measure boreholes are completed on each of two panels in years 1 through 3 and on one panel in year 4 in the northern Alabama area.

BASIS OF COSTING

The base cost of equipment and services in 1985 for the gob hole system were provided by the mining industry. The costs for the cross-measure system are based on Bureau studies in the Lower Kittanning Coalbed in 1982. These costs are updated to 1985 dollars on the basis of estimates provided by drilling companies and vendors of equipment and services.

After base year 0 (1985), all equipment and services costs, with the exception of electric power, are escalated 3.5, 4.0, 4.5, 5.0, and 5.5 pct for years 1 through 5 (1986-1990), respectively. Electric power cost is escalated 5.0 pct/yr.

Wage rates for years 0 through 3 (1985 to 1988) are in accordance with the National Bituminous Coal Wage Agreement of 1984. Wage rates for years 4 and 5 (1989 and 1990) are escalated 0.5 pct/yr. Salaries of supervisors and technicians are based on estimates provided by industry.

Cost comparisons between the surface gob hole and cross-measure borehole systems were made by discounting annual capital and operating costs to 1985 dollars, using 15-pct present-worth discrete factors.

COST COMPARISON

The annual capital and operating costs for the gob hole and cross-measure borehole systems are in the appendix. Present-worth costs of the systems are displayed in figure 6 and table 3. The costs of the cross-measure system in central Pennsylvania and northern West Virginia are greater than the costs of the surface gob hole system by 10 and 18 pct, respectively. Although overburden in the northern West Virginia area is 50 pct greater and the quantity of gob gas drained is 100 pct greater than in the central Pennsylvania area, the undiscounted capital and operating cost of the surface gob hole system is only 6 pct greater in northern West Virginia than in central Pennsylvania. This cost differential exists primarily because surface drilling rights and electric power cost much less in northern West Virginia than they do in central Pennsylvania (tables A-1 and A-2),[5] which offsets higher costs due to increased depth and greater quantities of gas drained in the northern West Virginia

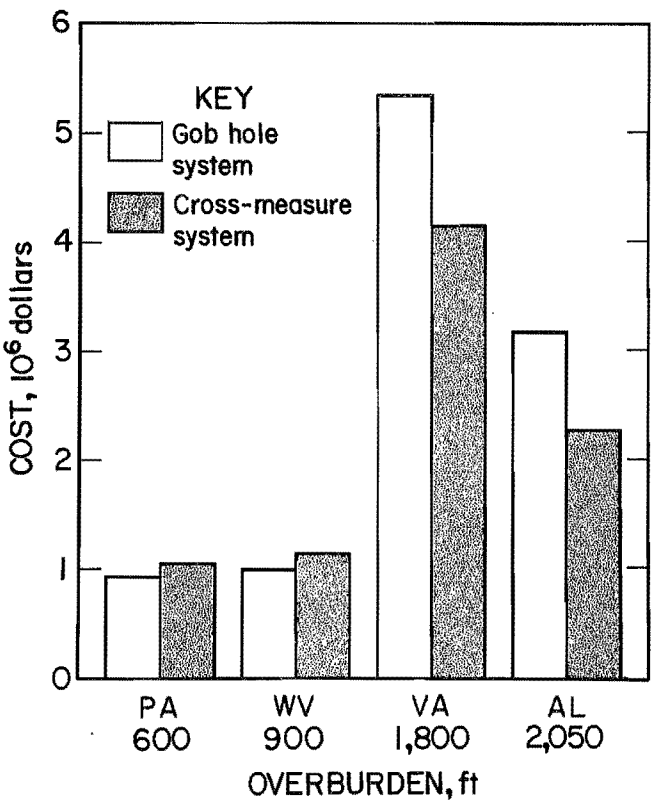

FIGURE 6.—Present-worth cost comparison.

[5]Tables with an A-prefix are in the appendix.

TABLE 3. - Cost comparison

Location and system	Overburden, ft	Methane drained, MMft^3	Undiscounted capital cost	Undiscounted operating cost	Undiscounted capital and operating cost	Present-worth capital and operating cost	Present-worth cost effectiveness,[1] pct
Central Pennsylvania:							
Gob hole.....	600	1.0	$1,004,200	$282,980	$1,287,180	$962,850	10
Cross-measure.....	600	1.0	366,330	1,152,460	1,518,790	1,055,060	NAp
Northern West Virginia:							
Gob hole.....	900	2.0	1,101,650	262,460	1,364,110	998,550	18
Cross-measure.....	900	2.0	386,650	1,171,180	1,557,830	1,175,330	NAp
Southern Virginia:							
Gob hole.....	1,800	14.0	6,070,780	1,143,400	7,214,180	5,356,380	NAp
Cross-measure.....	1,800	14.0	1,796,510	3,587,160	5,383,670	4,163,925	29
Northern Alabama:							
Gob hole.....	2,050	4.0	3,764,870	455,240	4,220,110	3,179,780	NAp
Cross-measure.....	2,050	4.0	1,237,950	1,545,580	2,783,530	2,296,360	38

[1]Cost effectiveness = better economic potential.

area. For example, surface drilling rights and electric power costs are $2,000 per hole and $0.025/kW•h, respectively, in the northern West Virginia area, compared with $5,000 per hole and $0.046/kW•h, respectively, in the central Pennsylvania area.

The present-worth costs of the surface gob hole system in southern Virginia and northern Alabama are greater than the costs of the cross-measure system by 29 and 38 pct, respectively.

Development, surface equipment, and site preparation for the 28 gob holes account for the higher cost of the surface gob hole system (table A-3) compared with the cross-measure system (table A-7) in the southern Virginia area. In northern Alabama, the costs of the gob hole system are greater because gob hole drilling and equipment costs (table A-4) are 33 pct greater than the combined costs of cross-measure drilling and methane drainage equipment (table A-8).

SUMMARY AND CONCLUSIONS

The surface gob hole system is 10 and 18 pct more cost effective in the central Pennsylvania and northern West Virginia areas, respectively, than the cross-measure borehole system. Overburden ranges from 600 ft (183 m) in central Pennsylvania to 900 ft (274 m) in northern West Virginia. In the southern Virginia and northern Alabama areas, the cross-measure system is 29 and 38 pct, respectively, more cost effective than the surface gob hole system. Overburden is 1,800 ft (549 m) in the southern Virginia area and 2,050 ft (625 m) in the northern Alabama area.

No assumptions can be made relative to the cost effectiveness of either method of gob gas control at other longwall mines in the States included in this report or in other States that have about the same overburden and quality of methane to be drained, because of the cost differences associated with the purchase of surface drilling rights, surface equipmnet, drilling contractor services, site preparation, and electric power. Comparative costs can be developed on a case-by-case basis only. It is hoped that the cost schedules in this report, which include equipment and service items listed by category, will be helpful in the development of costs for other locations.

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APPENDIX.--UNDISCOUNTED CAPITAL AND OPERATING COST TABLES

TABLE A-1. - Surface gob hole system, central Pennsylvania

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$15,700	NAp	NAp	NAp	NAp	NAp	$15,700
Surface drilling rights, 21 holes	105,070	NAp	NAp	NAp	NAp	NAp	105,070
Subtotal	120,770	NAp	NAp	NAp	NAp	NAp	120,770
Site preparation:							
Clear drilling sites	2,490	$2,580	$1,340	$1,400	$1,470	NAp	9,280
Construct roads	30,440	31,500	16,380	17,110	17,970	NAp	113,400
Install electric power	19,920	20,620	10,720	11,200	11,760	NAp	74,220
Subtotal	52,850	54,700	28,440	29,710	31,200	NAp	196,900
Surface equipment:							
Exhaust pumps, 4, 15-hp	7,440	NAp	NAp	NAp	NAp	NAp	7,440
Flame arrestors, 4, 8-in	4,360	NAp	NAp	NAp	NAp	NAp	4,360
Lightning protectors, 4	2,210	NAp	NAp	NAp	NAp	NAp	2,210
Fences, 3, 10- by 10- by 6-ft	1,310	NAp	NAp	NAp	NAp	NAp	1,310
Installation	NAp	2,490	2,570	2,680	2,800	$3,680	14,220
Subtotal	15,320	2,490	2,570	2,680	2,800	3,680	29,540
Gob hole equipment:							
Casing, 500 ft per hole, 8-in-ID, × $12/ft	NAp	36,000	37,440	19,560	20,540	21,670	135,210
Baskets, $220 per hole	NAp	1,370	1,420	740	780	820	5,130
Bottom plug and seal, $200 per hole	NAp	1,240	1,290	620	650	680	4,480
Subtotal	NAp	38,610	40,150	20,920	21,970	23,170	144,820
Gob hole drilling:							
Drill:							
500 ft per hole, 12-in-diam, × $25/ft	NAp	77,630	80,740	42,190	44,300	46,730	291,590
100 ft per hole, 8-in-ID, × $14.30/ft	NAp	8,880	9,240	4,420	4,640	4,900	32,080
Set casing, baskets, and grout, $2,225 per hole	NAp	13,810	14,360	6,910	7,250	7,650	49,980
Welding, $336 per hole	NAp	2,090	2,170	1,040	1,090	1,150	7,540
Subtotal	NAp	102,410	106,510	54,560	57,280	60,430	381,190
Supervision, office, general overhead, and contingency	28,340	29,730	26,650	16,180	16,790	13,090	130,980
Capitol cost	217,280	227,940	204,320	124,050	130,240	100,370	1,004,200
OPERATING COST							
Surface operation:							
Methane sampling and maintenance, 2 h/d × 365 days × $25.90 h	NAp	19,570	20,350	21,270	22,330	23,560	107,080
Electric for exhaust pumps, 4, 15-hp, × 8,760 h/yr × $0.046 kW·h	NAp	18,940	19,890	20,880	21,930	23,030	104,670
Seal gob holes, $1,500 per hole	NAp	6,000	6,210	6,460	6,750	8,900	34,320
Subtotal	NAp	44,510	46,450	48,610	51,010	55,490	246,070
Supervision, office, general overhead, and contingency	NAp	6,680	6,970	7,290	7,650	8,320	36,910
Operating cost	NAp	51,190	53,420	55,900	58,660	63,810	282,980
Capital and operating cost	217,280	279,130	257,740	179,950	188,900	164,180	1,287,180

NAp Not applicable.

TABLE A-2. - Surface gob hole system, northern West Virginia

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$15,700	NAp	NAp	NAp	NAp	NAp	$15,700
Surface drilling rights, 21 holes	42,070	NAp	NAp	NAp	NAp	NAp	42,070
Subtotal	57,770	NAp	NAp	NAp	NAp	NAp	57,770
Site preparation:							
Clear drilling sites	2,640	$2,730	$1,420	$1,480	$1,560	NAp	9,830
Construct roads	30,600	31,670	16,470	17,210	18,070	NAp	114,020
Install electric power	19,920	20,620	10,720	11,200	11,760	NAp	74,220
Subtotal	53,160	55,020	28,610	29,890	31,390	NAp	198,070
Surface equipment:							
Exhaust pumps, 4, 20-hp	8,840	NAp	NAp	NAp	NAp	NAp	8,840
Flame arrestors, 4, 8-in	4,360	NAp	NAp	NAp	NAp	NAp	4,360
Lightning protectors, 4	2,210	NAp	NAp	NAp	NAp	NAp	2,210
Fences, 3, 10- by 10- by 6-ft	1,310	NAp	NAp	NAp	NAp	NAp	1,310
Installation	NAp	2,490	2,570	2,680	2,800	$3,680	14,220
Subtotal	16,720	2,490	2,570	2,680	2,800	3,680	30,940
Gob hole equipment:							
Casing, 900 ft per hole, 7.0-in-ID, x $8.50/ft	NAp	47,510	49,410	23,640	24,820	26,190	171,570
Slotting, $4.50 per hole	NAp	2,790	2,910	1,390	1,460	1,540	10,090
Formation packer installed, $5,300 per hole	NAp	32,910	34,230	16,620	17,450	18,410	119,620
Subtotal	NAp	83,210	86,550	41,650	43,730	46,140	301,280
Gob hole drilling:							
Drill, 900 ft per hole, 8.75-in-diam, x $15/ft	NAp	83,840	87,190	45,560	47,830	50,460	314,880
Set casing and grout, $2,100 per hole	NAp	13,040	13,560	6,490	6,810	7,190	47,090
Welding, $340 per hole	NAp	2,110	2,200	1,150	1,200	1,270	7,930
Subtotal	NAp	98,990	102,950	53,200	55,840	58,920	369,900
Supervision, office, general overhead, and contingency	19,150	35,960	33,100	19,110	20,060	16,310	143,690
Capital cost	146,800	275,670	253,780	146,530	153,820	125,050	1,101,650
OPERATING COST							
Surface operation:							
Methane sampling and maintenance, 2 h/d x 365 days x $25.90/h	NAp	19,570	20,350	21,270	22,330	23,560	107,080
Electric for exhaust pumps, 4, 20-hp, x 8,760 h/yr x $0.025 kW·h	NAp	13,720	14,410	15,130	15,890	16,680	75,830
Seal gob holes, $2,000 per hole	NAp	8,280	8,610	9,000	9,450	9,970	45,310
Subtotal	NAp	41,570	43,370	45,400	47,670	50,210	228,220
Supervision, office, general overhead, and contingency	NAp	6,240	6,510	6,810	7,150	7,530	34,240
Operating cost	NAp	47,810	49,880	52,210	54,820	57,740	262,460
Capital and operating cost	146,800	323,480	303,660	198,740	208,640	182,790	1,364,110

NAp Not applicable.

TABLE A-3. - Surface gob hole system, southern Virginia

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$76,720	NAp	NAp	NAp	NAp	NAp	$76,720
Surface drilling rights, 28 holes	420,000	NAp	NAp	NAp	NAp	NAp	420,000
Subtotal	496,720	NAp	NAp	NAp	NAp	NAp	496,720
Site preparation:							
Clear drilling sites	12,000	$12,420	$12,920	$13,500	$7,090	NAp	57,930
Construct roads	144,000	149,040	155,000	161,980	85,040	NAp	695,060
Install electric power	240,000	248,400	258,340	269,960	141,730	NAp	1,158,430
Subtotal	396,000	409,860	426,260	445,440	233,860	NAp	1,911,420
Surface equipment:							
Exhaust pumps, 4, 100-hp	120,000	NAp	NAp	NAp	NAp	NAp	120,000
Fences, 4, 10- by 10- by 6-ft	1,760	NAp	NAp	NAp	NAp	NAp	1,760
Installation	NAp	39,330	40,900	42,740	44,880	$23,670	191,520
Subtotal	121,760	39,330	40,900	42,740	44,880	23,670	313,280
Gob hole equipment:							
Casing, 1,800 ft per hole, 9-in-ID, × $10.80/ft	NAp	120,720	125,550	131,200	137,760	72,670	587,900
Formation packer installed, $5,300 per hole	NAp	32,910	34,230	35,770	37,560	19,810	160,280
Bottom plug and seal, $2,150 per hole	NAp	13,350	13,890	14,510	15,240	8,040	65,030
Subtotal	NAp	166,980	173,670	181,480	190,560	100,520	813,210
Gob hole drilling:							
Drill, 1,800 ft per hole, 12.25-in-diam, × $30/ft	NAp	335,340	348,750	364,450	382,670	201,860	1,633,070
Set casing, weld and grout, $3,500 per hole	NAp	22,830	23,730	24,800	26,040	13,840	111,240
Subtotal	NAp	358,170	372,480	389,250	408,710	215,700	1,744,310
Supervision, office, general overhead, and contingency	152,170	146,150	152,000	158,840	131,700	50,980	791,840
Capital cost	1,166,650	1,120,490	1,165,310	1,217,750	1,009,710	390,870	6,070,780
OPERATING COST							
Surface operation:							
Methane sampling and maintenance, 4 h/d × 365 days × $25.90/h	NAp	39,140	40,700	42,530	44,660	23,560	190,590
Electric for exhaust pumps, 4, 100-hp, × 8,760 h/yr × $0.05 kW·h	NAp	137,230	144,100	151,300	158,870	166,810	758,310
Seal gob holes, $1,500 per hole	NAp	9,320	9,690	10,120	10,630	5,610	45,370
Subtotal	NAp	185,690	194,490	203,950	214,160	195,980	994,270
Supervision, office, general overhead, and contingency	NAp	27,850	29,170	30,590	32,120	29,400	149,130
Operating cost	NAp	213,540	223,660	234,540	246,280	225,380	1,143,400
Capital and operating cost	1,166,650	1,334,030	1,388,970	1,452,290	1,255,990	616,250	7,214,180

NAp Not applicable.

TABLE A-4. - Surface gob hole system, northern Alabama

Year	0	1	2	3	4	Total
CAPITAL COST						
Development:						
Project planning, surveying and mapping	$20,180	NAp	NAp	NAp	NAp	$20,180
Surface drilling rights, 28 holes	140,000	NAp	NAp	NAp	NAp	140,000
Subtotal	160,180	NAp	NAp	NAp	NAp	160,180
Site preparation:						
Clear drilling sites	3,320	$3,440	$3,570	$1,870	NAp	12,220
Construct roads	40,580	42,000	43,680	22,820	NAp	149,080
Install electric power	26,560	27,490	28,590	14,940	NAp	97,580
Subtotal	70,460	72,930	75,840	39,630	NAp	258,860
Surface equipment:						
Exhaust pumps, 4, 40-hp	51,000	NAp	NAp	NAp	NAp	51,000
Flame arrestors, 4, 10-in	7,000	NAp	NAp	NAp	NAp	7,000
Lightning protectors, 4	2,210	NAp	NAp	NAp	NAp	2,210
Fences, 4, 10- by 10- by 6-ft	1,760	NAp	NAp	NAp	NAp	1,760
Installation	NAp	5,160	5,360	5,600	$2,940	19,060
Subtotal	61,970	5,160	5,360	5,600	2,940	81,030
Gob hole equipment:						
Casing:						
150 ft per hole, 13.38-in-ID, x $14.00/ft	NAp	17,390	18,080	18,900	9,920	64,290
1900 ft per hole, 9.63-in-ID, x $10.50/ft	NAp	165,190	171,790	179,520	94,250	610,750
Slotting, $1,300 per hole	NAp	10,760	11,190	11,700	6,140	39,790
Formation packer installed, $5,300 per hole	NAp	43,880	45,640	47,690	25,040	162,250
Subtotal	NAp	237,220	246,700	257,810	135,350	877,080
Gob hole drilling:						
Drill:						
150 ft per hole, 17.50-in diam, x $26.50/ft	NAp	32,910	34,230	35,770	18,780	121,690
1,900 ft per hole, 12.25-in diam, x $26.50/ft	NAp	416,900	433,580	453,090	237,870	1,541,440
Logging, $2,500 per hole	NAp	20,700	21,530	22,500	11,810	76,540
Set casing and grout, $5,000 per hole	NAp	41,400	43,060	44,990	23,620	153,070
Welding, $128 per hole	NAp	1,060	1,100	1,150	600	3,910
Subtotal	NAp	512,970	533,500	557,500	292,680	1,896,650
Supervision, office, general overhead, and contingency	43,890	124,240	129,210	129,080	64,650	491,070
Capital cost	336,500	952,520	990,610	989,620	495,620	3,764,870
OPERATING COST						
Surface operation:						
Methane sampling and maintenance, 4 h/d x 365 days x $25.90/h	NAp	39,140	40,700	42,530	22,330	144,700
Electric for exhaust pumps, 4, 40-hp, x 8,760 h/yr x $0.043 kW·h	NAp	55,000	57,750	60,640	31,840	205,230
Seal gob holes, $1,500 per hole		12,420	12,920	13,500	7,090	45,930
Subtotal	NAp	106,560	111,370	116,670	61,260	395,860
Supervision, office, general overhead, and contingency	NAp	15,980	16,710	17,500	9,190	59,380
Operating cost	NAp	122,540	128,080	134,170	70,450	455,240
Capital and operating cost	336,500	1,075,060	1,118,690	1,123,790	566,070	4,220,110

NAp Not applicable.

TABLE A-5. - Cross-measure system, central Pennsylvania

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$3,170	NAp	NAp	NAp	NAp	NAp	$3,170
Training 6 persons, 24 h each	4,640	NAp	NAp	NAp	NAp	NAp	4,640
Surface drilling rights, 1 hole	5,000	NAp	NAp	NAp	NAp	NAp	5,000
Subtotal	12,810	NAp	NAp	NAp	NAp	NAp	12,810
Site preparation:							
Clear drilling sites	420	NAp	NAp	NAp	NAp	NAp	420
Construct road	5,080	NAp	NAp	NAp	NAp	NAp	5,080
Install electric power	3,320	NAp	NAp	NAp	NAp	NAp	3,320
Subtotal	8,820	NAp	NAp	NAp	NAp	NAp	8,820
Surface equipment:							
Exhaust pumps:							
1, 50-hp	10,810	NAp	NAp	NAp	NAp	NAp	10,810
1, 15-hp	1,860	NAp	NAp	NAp	NAp	NAp	1,860
Flame arrestors:							
1, 8-in	1,090	NAp	NAp	NAp	NAp	NAp	1,090
1, 6-in	700	NAp	NAp	NAp	NAp	NAp	700
1, 4-in	400	NAp	NAp	NAp	NAp	NAp	400
Lightning protectors, 2	1,120	NAp	NAp	NAp	NAp	NAp	1,120
Fence, 1, 18- by 30- by 8-ft	2,970	NAp	NAp	NAp	NAp	NAp	2,970
Installation	NAp	$1,200	NAp	NAp	NAp	NAp	1,200
Subtotal	18,950	1,200	NAp	NAp	NAp	NAp	20,150
Vertical borehole equipment:							
Casing, 600 ft per hole, 8-in-ID, × $12/ft	NAp	7,450	NAp	NAp	NAp	NAp	7,450
Baskets and grouting, $1,905 per hole	NAp	1,970	NAp	NAp	NAp	NAp	1,970
Subtotal	NAp	9,420	NAp	NAp	NAp	NAp	9,420
Vertical borehole drilling:							
Drill, 600 ft per hole, 12-in-diam, × $25/ft	NAp	15,530	NAp	NAp	NAp	NAp	15,530
Set casing, baskets and grout, $2,530 per hole	NAp	2,620	NAp	NAp	NAp	NAp	2,620
Welding, $336 per hole	NAp	350	NAp	NAp	NAp	NAp	350
Subtotal	NAp	18,500	NAp	NAp	NAp	NAp	18,500

Cross-measure drilling equipment:							
Drill unit, 20-hp, and drill rods	39,100	NAp	NAp	NAp	NAp	NAp	39,100
Core barrels, 3, and 1 adapter	5,710	NAp	NAp	NAp	NAp	NAp	5,710
Diamond bits, 8, 1.9-in	8,600	NAp	NAp	NAp	NAp	NAp	8,600
Grout pump and grout	2,930	NAp	NAp	NAp	NAp	NAp	2,930
Subtotal	56,340	NAp	NAp	NAp	NAp	NAp	56,340
Methane drainage equipment:							
Standpipes, 189, 2.25-in-OD	3,640	NAp	NAp	NAp	NAp	NAp	3,640
Standpipe accessories, 54 sets	8,320	NAp	NAp	NAp	NAp	NAp	8,320
Polyethylene pipe, 13,000 ft, 8-in-ID	90,350	NAp	NAp	NAp	NAp	NAp	90,350
Pipe accessories, lot	1,300	NAp	NAp	NAp	NAp	NAp	1,300
Copper wire, 73,000 ft	4,990	NAp	NAp	NAp	NAp	NAp	4,990
Gate valves, 8, 8-in	2,650	NAp	NAp	NAp	NAp	NAp	2,650
Check valves, 75, 1-in	2,900	NAp	NAp	NAp	NAp	NAp	2,900
Fusion machine, 1	11,380	NAp	NAp	NAp	NAp	NAp	11,380
Installation	NAp	21,320	$16,750	$9,250	$9,810	$9,850	66,980
Subtotal	125,530	21,320	16,750	9,250	9,810	9,850	192,510
Supervision, office, general overhead, and contingency	33,370	7,570	2,510	1,390	1,470	1,480	47,780
Capital cost	255,820	58,010	19,260	10,640	11,280	11,330	366,330
OPERATING COST							
Cross-measure drilling:							
Drill setup	NAp	43,330	45,060	23,540	24,720	26,080	162,730
Drilling and maintenance	NAp	129,990	135,190	70,640	74,170	78,250	488,240
Set standpipe, grout and connect	NAp	43,330	45,060	23,540	24,720	26,080	162,730
Drill bit rework	NAp	720	750	780	NAp	NAp	2,250
Electric for drill	NAp	3,600	3,780	1,980	2,080	2,180	13,620
System inspection	NAp	7,980	8,300	4,340	4,560	4,810	29,990
Subtotal	NAp	228,950	238,140	124,820	130,250	137,400	859,560
Surface operation:							
Methane sampling and maintenance	NAp	9,780	10,170	10,630	11,160	11,770	53,510
Electric for exhaust pumps	NAp	15,780	16,570	17,400	18,270	19,180	87,200
Seal vertical gob hole, $1,500 per hole	NAp	NAp	NAp	NAp	NAp	1,870	1,870
Subtotal	NAp	25,560	26,740	28,030	29,430	32,910	142,580
Supervision, office, general overhead, and contingency	NAp	38,180	39,730	22,930	23,950	25,530	150,320
Operating cost	NAp	292,690	304,610	175,780	183,630	195,740	1,152,460
Capital and operating cost	255,820	350,700	323,870	186,420	194,910	207,070	1,518,790

NAp Not applicable.

TABLE A-6. - Cross-measure system, northern West Virginian

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$3,170	NAp	NAp	NAp	NAp	NAp	$3,170
Training, 6 persons, 24 h each	3,480	NAp	NAp	NAp	NAp	NAp	3,480
Surface drilling rights, 1 hole	2,000	NAp	NAp	NAp	NAp	NAp	2,000
Subtotal	8,650	NAp	NAp	NAp	NAp	NAp	8,650
Site preparation:							
Clear drilling sites	440	NAp	NAp	NAp	NAp	NAp	440
Construct road	5,100	NAp	NAp	NAp	NAp	NAp	5,100
Install electric power	3,320	NAp	NAp	NAp	NAp	NAp	3,320
Subtotal	8,860	NAp	NAp	NAp	NAp	NAp	8,860
Surface equipment:							
Exhaust pumps, 2, 60-hp	35,000	NAp	NAp	NAp	NAp	NAp	35,000
Flame arrestor, 1, 10-in; 2, 8-in	3,920	NAp	NAp	NAp	NAp	NAp	3,920
Lightning protectors, 3	1,660	NAp	NAp	NAp	NAp	NAp	1,660
Fence, 1, 18- by 30- by 8-ft	3,140	NAp	NAp	NAp	NAp	NAp	3,140
Installation	NAp	$1,720	NAp	NAp	NAp	NAp	1,720
Subtotal	43,720	1,720	NAp	NAp	NAp	NAp	45,440
Vertical borehole equipment:							
Casing, 900 ft per hole, 7.0-in-ID, × $8.50/ft	NAp	7,920	NAp	NAp	NAp	NAp	7,920
Vertical borehole drilling:							
Drill, 900 ft, 8.75-in-diam, × $15/ft	NAp	13,970	NAp	NAp	NAp	NAp	13,970
Set casing and grout, $2,100 per hole	NAp	2,170	NAp	NAp	NAp	NAp	2,170
Welding, $340 per hole	NAp	350	NAp	NAp	NAp	NAp	350
Subtotal	NAp	16,490	NAp	NAp	NAp	NAp	16,490
Cross-measure drilling equipment:							
Drill unit, 20-hp, and drill rods	39,100	NAp	NAp	NAp	NAp	NAp	39,100
Core barrels, 3, and 1 adapter	5,710	NAp	NAp	NAp	NAp	NAp	5,710
Diamond bits, 8, 1.9-in	8,600	NAp	NAp	NAp	NAp	NAp	8,600
Grout pump and grout	2,930	NAp	NAp	NAp	NAp	NAp	2,930
Subtotal	56,340	NAp	NAp	NAp	NAp	NAp	56,340

Methane drainage equipment:							
Standpipes, 189, 2.25-in-OD	3,640	NAp	NAp	NAp	NAp	NAp	3,640
Standpipe accessories, 54 sets	8,320	NAp	NAp	NAp	NAp	NAp	8,320
Polyethylene pipe, 13,000 ft, 8-in-ID	90,350	NAp	NAp	NAp	NAp	NAp	90,350
Pipe accessories, lot	1,300	NAp	NAp	NAp	NAp	NAp	1,300
Copper wire, 73,000 ft	4,990	NAp	NAp	NAp	NAp	NAp	4,990
Gate valves, 8, 8-in	2,650	NAp	NAp	NAp	NAp	NAp	2,650
Check valves, 75, 1-in	2,900	NAp	NAp	NAp	NAp	NAp	2,900
Fusion machine, 1	11,380	NAp	NAp	NAp	NAp	NAp	11,380
Installation	NAp	21,320	$16,750	$9,250	$9,810	$9,850	66,980
Subtotal	125,530	21,320	16,750	9,250	9,810	9,850	192,510
Supervision, office, general overhead, and contingency	36,470	7,120	2,510	1,390	1,470	1,480	50,440
Capital cost	279,570	54,570	19,260	10,640	11,280	11,330	386,650
OPERATING COST							
Cross-measure drilling:							
Drill setup	NAp	43,330	45,060	23,540	24,720	26,080	162,730
Drilling and maintenance	NAp	129,990	135,190	70,640	74,170	78,250	488,240
Set standpipe, grout and connect	NAp	43,330	45,060	23,540	24,720	26,080	162,730
Drill bit rework	NAp	NAp	720	750	780	NAp	2,250
Electric for drill	NAp	1,960	2,060	1,080	1,140	1,190	7,430
System inspection	NAp	7,980	8,260	4,310	4,530	4,780	29,860
Subtotal	NAp	226,590	236,350	123,860	130,060	136,380	853,240
Surface operation:							
Methane sampling and maintenance	NAp	9,780	10,170	10,630	11,160	11,770	53,510
Electric for exhaust pumps	NAp	20,420	20,590	21,620	22,700	23,840	109,170
Seal vertical gob hole, $2,000 per hole	NAp	NAp	NAp	NAp	NAp	2,490	2,490
Subtotal	NAp	30,200	30,760	32,250	33,860	38,100	165,170
Supervision, office, general overhead, and contingency	NAp	38,520	40,070	23,420	24,590	26,170	152,770
Operating cost	NAp	295,310	307,180	179,530	188,510	200,650	1,171,180
Capital and operating cost	279,570	349,880	326,440	190,170	199,790	211,980	1,557,830

NAp Not applicable.

TABLE A-7. - Cross-measure system, southern Virginia

Year	0	1	2	3	4	5	Total
CAPITAL COST							
Development:							
Project planning, surveying and mapping	$4,660	NAp	NAp	NAp	NAp	NAp	$4,660
Training, 8 persons, 24 h each	4,640	NAp	NAp	NAp	NAp	NAp	4,640
Surface drilling rights, 2 holes	30,000	NAp	NAp	NAp	NAp	NAp	30,000
Subtotal	39,300	NAp	NAp	NAp	NAp	NAp	39,300
Site preparation:							
Clear drilling sites	4,000	NAp	NAp	NAp	NAp	NAp	4,000
Construct roads	48,000	NAp	NAp	NAp	NAp	NAp	48,000
Install electric power	80,000	NAp	NAp	NAp	NAp	NAp	80,000
Subtotal	132,000	NAp	NAp	NAp	NAp	NAp	132,000
Surface equipment:							
Exhaust pumps:							
1, 60-hp	19,460	NAp	NAp	NAp	NAp	NAp	19,460
1, 200-hp	34,500	NAp	NAp	NAp	NAp	NAp	34,500
2, 350-hp	104,000	NAp	NAp	NAp	NAp	NAp	104,000
Fences, 2, 36- by 60- by 8-ft	5,940	NAp	NAp	NAp	NAp	NAp	5,940
Installation	NAp	$31,600	NAp	NAp	NAp	NAp	31,600
Subtotal	163,900	31,600	NAp	NAp	NAp	NAp	195,500
Vertical borehole equipment:							
Casing, 1,800 ft per hole, 9.0-in-ID, × $10.80/ft	NAp	40,240	NAp	NAp	NAp	NAp	40,240
Bottom plug and seal, $2,150 per hole	NAp	4,450	NAp	NAp	NAp	NAp	4,450
Subtotal	NAp	44,690	NAp	NAp	NAp	NAp	44,690
Vertical borehole drilling:							
Drill, 1,800 ft per hole, 12.25-in-diam, × $30/ft	NAp	111,780	NAp	NAp	NAp	NAp	111,780
Set casing, weld and grout, $4,900 per hole	NAp	9,800	NAp	NAp	NAp	NAp	9,800
Subtotal	NAp	121,580	NAp	NAp	NAp	NAp	121,580
Cross-measure drilling equipment:							
Drill unit, 1, 20-hp, and drill rods	39,100	NAp	NAp	NAp	NAp	NAp	39,100
Core barrels, 6, and 2 adapters	11,420	NAp	NAp	NAp	NAp	NAp	11,420
Diamond bits, 16, 2.5-in	24,080	NAp	NAp	NAp	NAp	NAp	24,080
Grout pump and grout	4,890	NAp	NAp	NAp	NAp	NAp	4,890
Subtotal	79,490	NAp	NAp	NAp	NAp	NAp	79,490

Methane drainage equipment:							
Standpipes, 378, 4.0-in-OD	9,830	NAp	NAp	NAp	NAp	NAp	9,830
Standpipe accessories, 378 sets	60,480	NAp	NAp	NAp	NAp	NAp	60,480
Polyethylene pipe, 52,500 ft, 8-in-ID	502,950	NAp	NAp	NAp	NAp	NAp	502,950
Polyethylene pipe, 15,600 ft, 12-in-ID	68,430	NAp	NAp	NAp	NAp	NAp	68,430
Pipe accessories, lot	68,130	NAp	NAp	NAp	NAp	NAp	68,130
Copper wire, 126,000 ft	8,690	NAp	NAp	NAp	NAp	NAp	8,690
Butterfly valves, 4, 12-in	2,800	NAp	NAp	NAp	NAp	NAp	2,800
Gate valves, 25, 8-in	13,730	NAp	NAp	NAp	NAp	NAp	13,730
Check valves, 378, 1-in	14,620	NAp	NAp	NAp	NAp	NAp	14,620
Fusion machine, 1	11,380	NAp	NAp	NAp	NAp	NAp	11,380
Installation	NAp	67,370	48,560	23,010	24,160	25,490	188,590
Subtotal	761,040	67,370	48,560	23,010	24,160	25,490	949,630
Supervision, office, general overhead, and contingency	176,360	39,790	7,280	3,450	3,620	3,820	234,320
Capital cost	1,352,090	305,030	55,840	26,460	27,780	29,310	1,796,510
OPERATING COST							
Cross-measure drilling:							
Drill setup	NAp	90,000	93,600	48,900	51,350	54,170	338,020
Drilling and maintenance	NAp	269,990	280,790	146,710	154,050	162,520	1,014,060
Set standpipe, grout and connect	NAp	90,000	93,600	48,900	51,350	54,170	338,020
Drill bit rework	NAp	1,450	1,510	1,570	NAp	NAp	4,530
Electric for drill	NAp	7,360	7,660	4,000	4,200	4,430	27,650
System inspection	NAp	15,940	16,580	17,330	9,100	9,600	68,550
Subtotal	NAp	474,740	493,740	267,410	270,050	284,890	1,790,830
Surface operation:							
Methane sampling and maintenance	NAp	19,570	20,350	21,270	22,330	23,560	107,080
Electric for exhaust pumps	NAp	220,340	231,360	242,930	255,070	267,830	1,217,530
Seal vertical gob hole, $1,500 per hole	NAp	NAp	NAp	NAp	NAp	3,740	3,740
Subtotal	NAp	239,910	251,710	264,200	277,400	295,130	1,328,350
Supervision, office, general overhead, and contingency	NAp	107,200	111,820	79,740	82,120	87,100	467,980
Operating cost	NAp	821,850	857,270	611,350	629,570	667,120	3,587,160
Capital and operating cost	1,352,090	1,126,880	913,110	637,810	657,350	696,430	5,383,670

NAp Not applicable.

TABLE A-8. - Cross-measure system, northern Alabama

Year	0	1	2	3	4	Total
CAPITAL COST						
Development:						
Project planning, surveying and mapping	$3,170	NAp	NAp	NAp	NAp	$3,170
Training, 8 persons, 24 h each	4,640	NAp	NAp	NAp	NAp	4,640
Surface drilling rights, 1 hole	5,000	NAp	NAp	NAp	NAp	5,000
Subtotal	12,810	NAp	NAp	NAp	NAp	12,810
Site preparation:						
Clear drilling sites, 1 hole	420	NAp	NAp	NAp	NAp	420
Construct road	5,080	NAp	NAp	NAp	NAp	5,080
Install electric power	3,320	NAp	NAp	NAp	NAp	3,320
Subtotal	8,820	NAp	NAp	NAp	NAp	8,820
Surface equipment:						
Exhaust pumps:						
1, 60-hp	19,460	NAp	NAp	NAp	NAp	19,460
2, 100-hp	52,400	NAp	NAp	NAp	NAp	52,400
Flame arrestor:						
1, 10-in	1,750	NAp	NAp	NAp	NAp	1,750
2, 12-in	4,800	NAp	NAp	NAp	NAp	4,800
Lightning protectors, 4	2,210	NAp	NAp	NAp	NAp	2,210
Fence, 1, 18- by 30- by 8-ft	3,140	NAp	NAp	NAp	NAp	3,140
Installation	NAp	2,570	NAp	NAp	NAp	2,570
Subtotal	83,760	2,570	NAp	NAp	NAp	86,330
Vertical borehole equipment:						
Casing:						
150 ft per hole, 13-3/8-in-ID, × $14.00/ft	NAp	2,170	NAp	NAp	NAp	2,170
1,900 ft per hole, 9-5/8-in-ID, × $10.50/ft	NAp	20,650	NAp	NAp	NAp	20,650
Subtotal	NAp	22,820	NAp	NAp	NAp	22,820
Vertical borehole drilling:						
Drill:						
150 ft per hole, 17.50-in-ID, × $26.50/ft	NAp	4,120	NAp	NAp	NAp	4,120
1,900 ft per hole, 12.25-in-ID, × $26.50/ft	NAp	52,110	NAp	NAp	NAp	52,110
Logging, $2,500 per hole	NAp	2,590	NAp	NAp	NAp	2,590
Set casing and grout, $5,850 per hole	NAp	6,060	NAp	NAp	NAp	6,060
Welding, $128 per hole	NAp	130	NAp	NAp	NAp	130
Subtotal	NAp	65,010	NAp	NAp	NAp	65,010

Cross-measure drilling equipment:						
Drill unit, 1, 20-hp, and drill rods	39,100	NAp	NAp	NAp	NAp	39,100
Core barrels, 5, and 2 adapters	9,500	NAp	NAp	NAp	NAp	9,500
Diamond bits, 12, 1.9-in	12,900	NAp	NAp	NAp	NAp	12,900
Grout pump and grout	3,910	NAp	NAp	NAp	NAp	3,910
Subtotal	65,410	NAp	NAp	NAp	NAp	65,410
Methane drainage equipment:						
Standpipes, 259, 2.25-in-OD	6,730	NAp	NAp	NAp	NAp	6,730
Standpipe accessories, 259 sets	41,400	NAp	NAp	NAp	NAp	41,400
Polyethylene pipe:						
52,500-ft, 8-in-ID	502,950	NAp	NAp	NAp	NAp	502,950
2,800-ft, 10-in-ID	28,500	NAp	NAp	NAp	NAp	28,500
Pipe accessories, lot	17,460	NAp	NAp	NAp	NAp	17,460
Copper wire, 110,000-ft	7,540	NAp	NAp	NAp	NAp	7,540
Gate valves, 9, 8-in	2,980	NAp	NAp	NAp	NAp	2,980
Check valves, 259, 1-in	10,000	NAp	NAp	NAp	NAp	10,000
Fusion machine, 1	11,380	NAp	NAp	NAp	NAp	11,380
Installation	NAp	67,370	$46,300	$47,170	$25,490	186,330
Subtotal	628,940	67,370	46,300	47,170	25,490	815,270
Supervision, office, general overhead, contingency	119,960	23,670	6,950	7,080	3,820	161,480
Capital cost	919,700	181,440	53,250	54,250	29,310	1,237,950
OPERATING COST						
Cross-measure drilling:						
Drill setup	NAp	61,660	64,130	67,010	35,180	227,980
Drilling and maintenance	NAp	184,990	192,390	200,090	105,050	682,520
Set standpipe, grout and connect	NAp	61,660	64,130	67,010	35,180	227,980
Drill bit rework	NAp	1,090	1,130	1,180	NAp	3,400
Electric for drill	NAp	4,790	5,030	5,280	2,770	17,870
System inspection	NAp	11,960	12,430	12,990	6,820	44,200
Subtotal	NAp	326,150	339,240	353,560	185,000	1,203,950
Surface operation:						
Methane sampling and maintenance	NAp	9,780	10,170	10,630	11,160	41,740
Electric for exhaust pumps	NAp	25,870	27,160	28,520	14,970	96,520
Seal vertical gob hole, $1,500 per hole	NAp	NAp	NAp	NAp	1,770	1,770
Subtotal	NAp	35,650	37,330	39,150	27,900	140,030
Supervision, office, general overhead, and contingency	NAp	54,270	56,490	58,910	31,930	201,600
Operating cost	NAp	416,070	433,060	451,620	244,830	1,545,580
Capital and operating cost	919,700	597,510	486,310	505,870	274,140	2,783,530

NAp Not applicable.

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